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Joint Polar Satellite System (JPSS) Operational Algorithm Description (OAD) Document for VIIRS Sea Surface Temperature (SST) Environmental Data Record (EDR) Software

For Public Release

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National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

Joint Polar Satellite System (JPSS)
Operational Algorithm Description (OAD) Document for VIIRS Sea Surface Temperature (SST) Environmental Data Record (EDR) Software
JPSS Electronic Signature Page

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Preface

This document is under JPSS Ground Algorithm ERB configuration control. Once this document is approved, JPSS approved changes are handled in accordance with Class I and Class II change control requirements as described in the JPSS Configuration Management Procedures, and changes to this document shall be made by complete revision.

Any questions should be addressed to:

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Change History Log

Revision	Effective Date	Description of Changes (Reference the CCR & CCB/ERB Approve Date)
Original	05/20/2011	**474-CCR-11-0077:** This version baselines D36815, Operational Algorithm Description Document for VIIRS Sea Surface Temperature (SST) EDR, Rev B, dated 05/19/2010, as a JPSS document version Rev –. This is the version that was approved for NPP launch. Per NPOESS CDFCB - External, Volume V – Metadata, doc number D34862-05, this has been approved for Public Release into CLASS. This CCR was approved by the JPSS Algorithm ERB on May 20. 2011.
Revision A	01/18/2012	**474-CCR-11-0255:** This version baselines 474-00061, Joint Polar Satellite System (JPSS) Operational Algorithm Description (OAD) Document for VIIRS Sea Surface Temperature (SST) Environmental Data Record (EDR) Software, for the Mx 6 IDPS release. This CCR was approved by the JPSS Algorithm ERB on January 18, 2012.
Revision B	05/14/2013	**474-CCR-13-0948:** This version authorizes 474-00061, JPSS OAD Document for VIIRS SST EDR Software, for the Mx 7.0 IDPS release. Includes **ECR-ALG-0037**, which contains Raytheon PCR031522; OAD: Update to SST algorithm to clarify conditions for degraded quality flags (DR4845) in Section 2.1.2.5. Includes Raytheon PCR032720; 474-CCR-13-0916/ECR-ALG-0037: Update applicable OAD filenames/template/Rev/etc. for Mx7 Release.

NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS)

OPERATIONAL ALGORITHM DESCRIPTION DOCUMENT FOR SEA SURFACE TEMPERATURE (SST)

SDRL No. S141
SYSTEM SPECIFICATION SS22-0096

RAYTHEON COMPANY
INTELLIGENCE AND INFORMATION SYSTEMS (IIS)
NPOESS PROGRAM
OMAHA, NEBRASKA

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TITLE: NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS) OPERATIONAL ALGORITHM DESCRIPTION DOCUMENT FOR SEA SURFACE TEMPERATURE (SST)

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Engineering & Manufacturing Development (EMD) Phase
Acquisitions &Operations Contract

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Operational Algorithm Description Document
VIIRS Sea Surface Temperature (SST) EDR

Document Number: D36815
Document Date: Sep 27, 2011 **Revision: C6**

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This document has been identified per the NPOESS Common Data Format Control Book – External Volume 5 Metadata, D34862-05, Appendix B as a document to be provided to the NOAA Comprehensive Large Array-data Stewardship System (CLASS) via the delivery of NPOESS Document Release Packages to CLASS.

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NORTHROP GRUMMAN
Raytheon

Revision/Change Record

Document Number D36815

Revision	Document Date	Revision/Change Description	Pages Affected
---	3-31-03	Initial Release.	All
A1	7-24-03	Updated to reflect IPO port.	5–7, 9–15, 19, 21-22
A2	9-24-03	Added cover sheet; Added ITAR Markings.	All
A3	10-13-03	Finalized for ACCB review.	All
A4	1-5-04	Updated to list units in input and output tables.	4,5
A5	1-30-04	ERB updates.	All
A6	5-5-04	Replaced most of PDL, updated inputs, small misc. corrections.	3-14
A7	5-11-05	Reflects NGST comment corrections plus inserted new logo and updated upper right header date, title/signature page dates, Revision/Change Record.	All
A8	5-1-06	13Jul05 - Removed export markings per 26May05 official policy change and under Section 1.3.3, Source Code and Test Data References, inserted a more detailed table listing paths to find applicable source code within the ClearCase configuration management tool. Reworded sentence under Section 2.3.1 and added a diagram under Section 2.3.1.1 to address Sid Jackson's concern. 25Jan06 – Made minor edits per Omaha's PRO Desk Instruction titled "OAD Procedures" checking for format standardization, updating coversheet copyright, updating TBD/TBR table, etc. 01May06 – Updated to reflect changes needed from CUT/CC PR.	All
A9	9-25-06	Updated document ID from D36815-IDPS-002 to D36815 per NGST DM.	All
A10	6-15-07	Delivered to NGST. Accept all changes after delivery.	All
A11	3-21-08	Updated per TM NP.EMD.2007.610.0002. Modified graceful degradation and data quality notification sections.	All
A12	9-12-08	New cover sheet, update references, acronym list, prepare for peer review. Delivered to NGST. Accepted all changes after delivery.	All
A13	01-18-09	Prepared for TIM.	All
A	3-18-09 5-06-09	Incorporated TIM comments and final preparation for ARB/ACCB. Removed TBS01 for Public Release (No roll of rev)	All Tables 1 & 19
B1	09-28-09	Updated Table 7 for PCR 21384	7
B2	12-01-09	Updated for RFA Nos. 235 and 631, updated Subcontract number.	Title pg. & 5-7

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Revision/Change Record

Document Number **D36815**

B	5-19-10	Prepared for TIM/ARB/ACCB	All
C1	8-18-10	Updated Table 1 & 2 due to omission of TM 2010.510.0005.Rev-C	Table 1 & 2
C2	8-27-10	ECR1061/PCR024068 update output product ranges	Table 7
C3	10-20-10	Implemented Tech Memo 2010.510.0074 as a part of the document convergence (RFA007)	All
C4	06-29-11	Updated due to ECR-ALG-0007 VIIRS SST_Drop 4.6.1	All
C5	09-21-11	Updated for PCR027399	14-15
C6	09-27-11	Updated OAD for PCR026625.	All

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1.0 INTRODUCTION

1.1 Objective

The purpose of the Operational Algorithm Description (OAD) document is to express, in computer-science terms, the remote sensing algorithms that produce the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) end-user data products. These products are individually known as Raw Data Records (RDRs), Temperature Data Records (TDRs), Sensor Data Records (SDRs) and Environmental Data Records (EDRs). In addition, any Intermediate Products (IPs) produced in the process are also described in the OAD.

The science basis of an algorithm is described in a corresponding Algorithm Theoretical Basis Document (ATBD). The OAD provides a software description of that science as implemented in the operational ground system -- the Data Processing Element (DPE).

The purpose of an OAD is two-fold:

1. Provide initial implementation design guidance to the operational software developer.
2. Capture the “as-built” operational implementation of the algorithm reflecting any changes needed to meet operational performance/design requirements.

An individual OAD document describes one or more algorithms used in the production of one or more data products. There is a general, but not strict, one-to-one correspondence between OAD and ATBD documents.

This particular document describes operational software implementation for the Visible/Infrared Imager/Radiometer Suite (VIIRS) Sea Surface Temperature (SST) Environmental Data Record (EDR).

1.2 Scope

The scope of this document is limited to the description of the core operational algorithm(s) required to create the VIIRS Sea Surface Temperature (SST) EDR. The theoretical basis for this algorithm is described in Section 3.3 of the VIIRS Sea Surface Temperature Algorithm Theoretical Basis Document (ATBD), 474-00048.

1.2.1 Document References

The science and system engineering documents relevant to the algorithms described in this OAD are listed in Table 1.

Table 1. Reference Documents

Document Title	Document Number/Revision	Revision Date
VIIRS Sea Surface Temperature Algorithm Theoretical Basis Document (ATBD)	474-00048	Latest
VIIRS Sea Surface Temperature Unit Level Detailed Design	Y2504 Ver. 5 Rev. 6	Mar 2003
VIIRS Surface Temperature Component Level Detailed Design	Y0010880 Ver. 5 Rev. 9	30 Jul 2004
VIIRS Surface Temperature Module Level Software Architecture	Y2473 Ver. 5 Rev. 12	30 Jul 2004
VIIRS Surface Temperature Module Level Data Dictionary	Y0011652 Ver. 5 Rev. 3	Dec 2003

Document Title	Document Number/Revision	Revision Date
VIIRS Surface Temperature Module Level Interface Control Document	Y3281 Ver. 5 Rev. 4	Dec 2003
VIIRS Algorithm Verification Status Report	D36812 Rev. 2.04	02 Dec 2003
VIIRS Radiometric Calibration Component Detailed Design Document	Y2490 Ver. 5 Rev. 4	30 Sep 2004
JPSS Environmental Data Record (EDR) Production Report (PR) for NPP	474-00012	Latest
NPOESS System Specification	SY15-0007 Rev L	10 Sep 07
JPSS Environmental Data Record (EDR) Interdependency Report (IR) for NPP	474-00007	Latest
NPP Mission Data Format Control Book and App A (MDFCB)	429-05-02-42_MDFCB	Latest
JPSS Common Data Format Control Book - External - –Block 1.2.2 (All Volumes)	474-00001-01-B0122 CDFCB-X Vol I 474-00001-02-B0122 CDFCB-X Vol II 474-00001-03-B0122 CDFCB-X Vol III 474-00001-04-01-B0122 CDFCB-X Vol IV Part 1 474-00001-04-02-B0122 CDFCB-X Vol IV Part 2 474-00001-04-03-B0122 CDFCB-X Vol IV Part 3 474-00001-04-04-B0122 CDFCB-X Vol IV Part 4 474-00001-05-B0122 CDFCB-X Vol V 474-00001-06-B0122 CDFCB-X Vol VI 474-00001-08-B0122 CDFCB-X Vol VIII	Latest
JPSS Common Data Format Control Book - External - Block 1.2.3 (All Volumes)	474-00001-01-B0123 CDFCB-X Vol I 474-00001-02-B0123 CDFCB-X Vol II 474-00001-03-B0123 CDFCB-X Vol III 474-00001-04-01-B0123 CDFCB-X Vol IV Part 1 474-00001-04-02-B0123 CDFCB-X Vol IV Part 2 474-00001-04-03-B0123 CDFCB-X Vol IV Part 3 474-00001-04-04-B0123 CDFCB-X Vol IV Part 4 474-00001-05-B0123 CDFCB-X Vol V 474-00001-06-B0123 CDFCB-X Vol VI 474-00001-08-B0123 CDFCB-X Vol VIII	Latest
NPP Command and Telemetry (C&T) Handbook	D568423 Rev. C	30 Sep 2008
JPSS CGS Data Processor Inter-subsystem Interface Control Document (DPIS ICD) Vol I - IV	IC60917-IDP-002	Latest
JPSS Program Lexicon	474-00175	Latest

Document Title	Document Number/Revision	Revision Date
NGST/SE technical memo – VIIRS SST QF Memo	NP-EMD.2005.510.0023	21 Feb 2005
NGST/SE technical memo – MS Engineering Memo_SST OAD Update.doc	NP-EMD.2005.510.0073	Jun 2005
NGST/SE technical memo – NPP_VIIRS_SST_OAD_Update_Drop46.doc	NP.EMD.2007.610.0002	09 Aug 2007
NGST/SE technical memo – Granule-Level Summary Exclusion Flag Definition Rev. C.doc	NP.EMD.2010.510.0005.Rev-C	02 Mar 2010
NGST/SE technical memo – Instructions to Update the OAD for the VIIRS Sea Surface Temperature	NP.EMD.2010.510.0074	16 Sep 2010
Joint Polar Satellite System (JPSS) Common Ground System (CGS) IDPS PRO Software User's Manual Part 2	UG60917-IDP-026	Latest

1.2.2 Source Code References

The science and operational code and associated documentation relevant to the algorithms described in this OAD are listed in Table 2.

Table 2. Source Code References

Reference Title	Reference Tag/Revision	Revision Date
VIIRS SST science-grade software	ISTN_VIIRS_NGST_4.6	19 Nov 2007
VIIRS SST operational software	I1.3.0.14	28 Jun 2005
NGST/SE technical memo – VIIRS SST QF Memo	NP-EMD.2005.510.0023	21 Feb 2005
OAD – VIIRS SST Rev A	Build 1.5.x.1-B (PCRs 15068 & 16178)	16 Apr 08 & 24 Mar 08
PCR 21384 (no code changes)	(OAD Rev B1)	28 Sep 2009
PCR 22882 [TM 2010.510.0005.Rev-C] (No OAD update required)	Build Sensor Characterization SC-09	14 Apr 2010
ACCB	OAD Rev B	19 May 2010
ECR1061/PCR024068 update output product ranges	(OAD Rev C2)	27 Aug 2010
Implemented TM 2010.510.0074 (No code update)(PCR024726)	(OAD Rev C3)	20 Oct 2010
VIIRS SST science-grade software	ISTN_VIIRS_NGST_4.6.1	13 Jan 2011
VIIRS SST operational software (PCRs 025921 & 026165)	ECR-A0007 Maintenance Build 1.5.05.E (OAD Rev-C4)	09 Mar 2011 & 29 Jun 2011 (OAD)
PCR027399 (OAD-no code updates)	(OAD Rev-C5)	21 Sep 2011
PCR0226625 (OAD update for ADL)	(OAD Rev-C6)	27 Sep 2011
OAD transitioned to JPSS Program – this table is no longer updated.		

2.0 ALGORITHM OVERVIEW

This algorithm is a statistical retrieval that employs linear regression techniques to derive skin and bulk SST from VIIRS infrared bands. Separate regression algorithms are used for day and night, and regression coefficients are determined separately for dry and moist stratification for the daytime algorithm.

Figure 1 depicts the basic processing flow of the SST algorithm. Inputs are the aforementioned VIIRS Sensor Data Records (SDR) for 3.7, 10.8, and 12.0 μm channels; VIIRS Cloud Mask (VCM); Aerosol Optical Thickness (AOT); and Ice Concentration; and National Centers for Environmental Prediction (NCEP) Skin Temperature. Outputs are the skin and bulk SSTs plus some Quality Flags (QF)s.

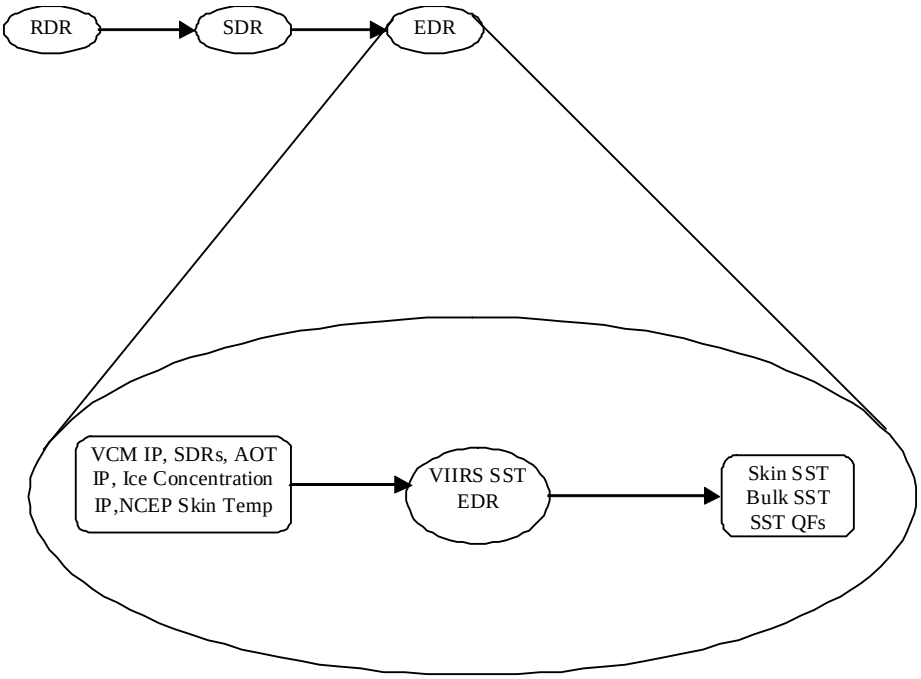

Figure 1. Basic Processing Flow for the VIIRS SST EDR

2.1 Sea Surface Temperature Description

2.1.1 Interfaces

To begin data processing, the Infrastructure (INF) Subsystem Software Item (SI) initiates the SST algorithm. The INF SI provides tasking information to the algorithm indicating which granule to process. The Data Management System (DMS) SI provides data storage and retrieval capability. A library of C++ classes is used to implement the SI interfaces. More information regarding these topics is found in document UG60917-IDP-026 with reference in particular to sections regarding PRO Common (CMN) processing and the IPO Model.

2.1.1.1 Inputs

Table 3 describes the VIIRS SST inputs for the SDR products, Table 4 describes the VIIRS SST inputs for the IPs, Table 5 describes the VIIRS SST inputs for the LUTs, and Table 6 details the

VCM Bits descriptions. Refer to the CDFCB-X, 474-00001, for a detailed description of the inputs.

Table 3. VIIRS SST Inputs – SDR Products

Input	Type	Description/Source	Units/Valid Range
Btemp	Real * 32 x M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS	Brightness Temperature of Band M12/ VIIRS 750 m resolution SDR	Kelvin / 203 K < BT_{M12} < 368 K Please refer to VIIRS Radiometric Calibration Document, Y2490-VIIRS-CAL-DDD NA_FLOAT32_FILL = - 999.9 MISS_FLOAT32_FILL = -999.8 ERR_FLOAT32_FILL = -999.5
Btemp	Real * 32 x M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS	Brightness Temperature of Band M15/ VIIRS 750 m resolution SDR	Kelvin / 190 K < BT_{M15} < 343 K Please refer to VIIRS Radiometric Calibration Document, Y2490-VIIRS-CAL-DDD NA_FLOAT32_FILL = - 999.9 MISS_FLOAT32_FILL = -999.8 ERR_FLOAT32_FILL = -999.5
Btemp	Real * 32 x [M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS]	Brightness Temperature of Band M16/ VIIRS 750 m resolution SDR	Kelvin / 190 K < BT_{M16} < 340 K Please refer to VIIRS Radiometric Calibration Document, Y2490-VIIRS-CAL-DDD NA_FLOAT32_FILL = - 999.9 MISS_FLOAT32_FILL = -999.8 ERR_FLOAT32_FILL = -999.5
sunzen	Real * 32 x M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS	Solar Zenith Angle/ VIIRS 750 m resolution SDR	Radians/ 0 to π
satzen	Real * 32 x M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS	Sensor Zenith Angle/ VIIRS 750 m resolution SDR	Radians/ 0 to 1.25

Table 4. SST Inputs - IPs and Ancillary Data

Input	Type	Description/Source	Units/Valid Range
AOT	Real * 32 x [M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS]	Slant path AOT at 550 nm	Unitless / 0 ≤ 2 NA_FLOAT32_FILL = - 999.9 MISS_FLOAT32_FILL = -999.8 ERR_FLOAT32_FILL = -999.5
Ice Fraction	Real * 32 x I_VIIRS_SDR_ROWS x I_VIIRS_SDR_COLS	Ice Fraction / VIIRS Ice Concentration IP	Unitless / 0.0 to 1.0
Ice Conc Weight	Real * 32 x I_VIIRS_SDR_ROWS x I_VIIRS_SDR_COLS	Ice Fraction/ VIIRS Ice Concentration IP	Unitless / 0.0 to 1.0
VCM	Char * 8 x M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS	See Table 6	See Table 6
Skin Temp	Real * 32 x M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS	NCEP Skin Temperature	Kelvin

Table 5. SST Inputs - LUTs

Input	Type	Description/Source	Units/Valid Range
SST Coeffs LUT	Real * 32 x [MAXCOEFFS][DYNGT][SBSST][ALG][NUM_REGIMES]	LUT of regression coefficients for calculation of bulk and skin SST	Unitless

Input	Type	Description/Source	Units/Valid Range
Configurable Parameters	See Table 11 for List of Tunable Algorithm Parameters	Ingest (ING)	See Table 11 for List of Tunable Algorithm Parameters
SST EDR DQTT	IngMsdThresholds_DQTT	Data quality threshold table provided by the ING subsystem	Defined in CDFCB-X, 474-00001

Table 6. VCM Bits Description (Relevant bits [passed into SST QF bytes] are shaded yellow)

BYTE	Bit	Flag Description Key	Result
0	0-1	Cloud Mask Quality	00=Poor, 01=Low, 10=Medium, 11=High
	2-3	Cloud Detection Result & Confidence Indicator	11=Confident Cloudy 10=Probably Cloudy 00=Confident Clear 01=Probably Clear
	4	Day / Night	0 = Night 1 = Day
	5	Snow / Ice Surface	1 = Snow/Ice 0 = No Snow/Ice
	6-7	Sun Glint	00 = None 01 = Geometry Based 10 = Wind Speed Based 11 = Geometry & Wind
1	0-2	Land / Water Background	000 = Land & Desert 001 = Land no Desert 010 = Inland Water 011 = Sea Water 101 = Coastal
	3	Shadow Detected	1 = Yes 0 = No
	4	Non Cloud Obstruction (Heavy Aerosol)	1 = Yes 0 = No
	5	Fire Detected	1 = Yes 0 = No
	6	Cirrus Detection (Solar) (RM9)	1 = Cloud 0 = No Cloud
	7	Cirrus Detection (IR) (BTM15-BTM16)	1 = Cloud 0 = No Cloud
2	0	IR Threshold Cloud Test (BTM15)	1 = Cloud 0 = No Cloud
	1	High Cloud (BTM12 - BTM16) Test	1 = Cloud 0 = No Cloud
	2	IR Temperature Difference Test (BTM14 - BTM15 & BTM15 - BTM16)	1 = Cloud 0 = No Cloud
	3	Temperature Difference Test (BTM15 - BTM12)	1 = Cloud 0 = No Cloud
	4	Temperature Difference Test (BTM12 – BTM13)	1 = Cloud 0 = No Cloud
	5	Visible Reflectance Test (RM5)	1 = Cloud 0 = No Cloud
	6	Visible Reflectance Test (RM7), also Visible Reflectance Test (RM1)	1 = Cloud 0 = No Cloud
	7	Visible Ratio Test (RM7/RM5)	1 = Cloud 0 = No Cloud
3	0-1	Adjacent Pixel Cloud Confident Value	11 = Confident Cloudy 10 = Probably Cloudy 00 = Confident Clear 01 = Probably Clear
	2	Conifer Boreal Forest	1 = Yes 0 = No
	3	Spatial Uniformity	1 = Yes 0 = No
	4	Dust candidate	1 = Yes 0 = No
	5	Smoke candidate	1 = Yes 0 = No
	6	Dust/Volcanic Ash	1 = Yes 0 = No
	7	SPARE	
4	0-7	SPARE	
5	0-2	Cloud Phase	000 = Not Executed 001 = Clear 010 = Partly Cloudy 011 = Water Cloud 100 = Supercooled Water/Mixed 101 = Opaque Ice Cloud 110 = Cirrus Cloud 111 = Cloud Overlap

BYTE	Bit	Flag Description Key	Result
	3	Thin Cirrus Flag	1 = Yes 0 = No
	4	Ephemeral Water Flag	1 = Yes 0 = No
	5-7	SPARE	

2.1.1.2 Outputs

Refer to the CDFCB-X, 474-00001, for a detailed description of the outputs.

The SST EDR produces five data fields (skin SST, bulk SST, and three quality flag fields) summarized in Table 7 for the scaled EDR product and Table 8 for the unscaled EDR product.

Table 7. Contents of the SST Scaled Output (EDR)

Output	Data Type/size	Description	Units
Skin SST	UInt16 * [M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS]	Skin Sea Surface Temperature	Kelvin / 265 to 320NA_UINT16_FILL = 65535 MISS_UINT16_FILL = 65534 ERR_UINT16_FILL = 65531
Bulk SST	UInt16 * [M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS]	Bulk Sea Surface Temperature	Kelvin / 265 to 320 NA_UINT16_FILL = 65535 MISS_UINT16_FILL = 65534 ERR_UINT16_FILL = 65531
SST EDR Quality Flags	UInt8 * 4 * [M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS]	Sea Surface Temperature Quality Flags. See Table 9 for detailed description.	See Table 9
Skin Scale	Float32	The scale value for the Sea Surface Temperature. This can be found by subtracting the min acceptable skin SST temperature from the max and dividing this result by 65527.	Unitless
Skin Offset	Float32	The offset value is the minimum acceptable temperature of the skin SST.	Unitless
Bulk Scale	Float32	The scale value for the Sea Surface Temperature. This can be found by subtracting the min acceptable bulk SST temperature from the max and dividing this result by 65527.	Unitless
Bulk Offset	Float32	The offset value is the minimum acceptable temperature of the bulk SST.	Unitless

Table 8. Contents of the SST Unscaled Output (EDR)

Output	Data Type/size	Description	Units
Skin SST	Real * 32* [M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS]	Skin Sea Surface Temperature	Kelvin / 271.0 to 313.0 NA_FLOAT32_FILL = - 999.9 MISS_FLOAT32_FILL = -999.8 ERR_FLOAT32_FILL = -999.5
Bulk SST	Real * 32* [M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS]	Bulk Sea Surface Temperature	Kelvin / 271.0 to 313.0 NA_FLOAT32_FILL = - 999.9 MISS_FLOAT32_FILL = -999.8 ERR_FLOAT32_FILL = -999.5
SST EDR Quality Flags	UInt8 * 4 * [M_VIIRS_SDR_ROWS x M_VIIRS_SDR_COLS]	Sea Surface Temperature Quality Flags; see Table 9 for detailed description	N/A

Table 9. VIIRS SST EDR/FEDR Quality Flags

Byte	VIIRS SST Flag	Result	Bits

Byte	VIIRS SST Flag	Result	Bits
0	Skin SST Quality	11 = High Quality 10 = Degraded 01 = Excluded 00 = Not retrieved	2
	Bulk SST Quality	11 = High Quality 10 = Degraded 01 = Excluded 00 = Not retrieved	2
	SST State	10 = Average 01 = Moist 00 = Dry / None	2
	Algorithm	1 = Triple Window 0 = Non-linear Split Window	1
	Day / Night	1 = Day 0 = Night	1
1	Bad LWIR Pixel	1 = Bad SDR 0 = Good SDR	1
	Bad SWIR Pixel	1 = Bad SDR 0 = Good SDR	1
	Cloud Confidence	11 = Confident Cloudy 10 = Probably Cloudy 01 = Probably Clear 00 = Confident Clear	2
	Adjacent Pixel Cloud Confident Value	11 = Confident Cloudy 10 = Probably Cloudy 01 = Probably Clear 00 = Confident Clear	2
	Thin Cirrus	1 = Thin Cirrus 0 = No Thin Cirrus	1
	Sea Ice	1 = Sea Ice 0 = No Sea Ice	1
2	Sun Glint	1 = Sun glint 0 = No sun glint	1
	Exclusion, AOT > 1	1 = Yes 0 = No	1
	Degraded, AOT > 0.6	1 = Yes 0 = No	1
	Exclusion, Not Ocean	1 = Not ocean 0 = Ocean	1
	Degraded, HCS limit	1 = Past HCS limit 0 = Within HCS limit	1
	Degraded, Sensor Zenith Angle > 40	1 = Yes 0 = No	1
	Skin SST Outside Range	1 = Out of range 0 = In range	1
	Bulk SST Outside Range	1 = Out of range 0 = In range	1
3	Skin SST Degraded, T > 305 K	1 = Degraded 0 = Not degraded	1
	Bulk SST Degraded, T > 305 K	1 = Degraded 0 = Not degraded	1
	Spare Bit		1
	Spare Bit		1
	Spare Bit		1
	Spare Bit		1
	Spare Bit		1
	Spare Bit		1

2.1.2 Algorithm Processing

This is the derived algorithm for the VIIRS SST algorithm and is a subclass of the ProCmnAlgorithm class. The class creates a list of input data items that are read from DMS and passes all of the required data into the SST algorithm itself. When the SST algorithm has finished processing that data, the output items are written to DMS. The SST algorithm produces both a scaled (VIIRS-SST-EDR) and unscaled (VIIRS-SST-FEDR) product. Figure 2 depicts overall data flow of this operational code. The code determines a skin and bulk SST for each pixel flagged as clear, probably clear, or probably cloudy by the VCM Intermediate Product (IP) that is non-ice ocean. If the pixel is flagged as probably clear or probably cloudy, the quality is flagged as excluded.

The baseline daytime retrieval algorithm used is the 2-band (M15, M16) non-linear split window algorithm. The baseline nighttime retrieval algorithm used is the 3-band (M12, M15, M16) triple window algorithm. If band M12 is not functioning at night, the non-linear split window algorithm is used.

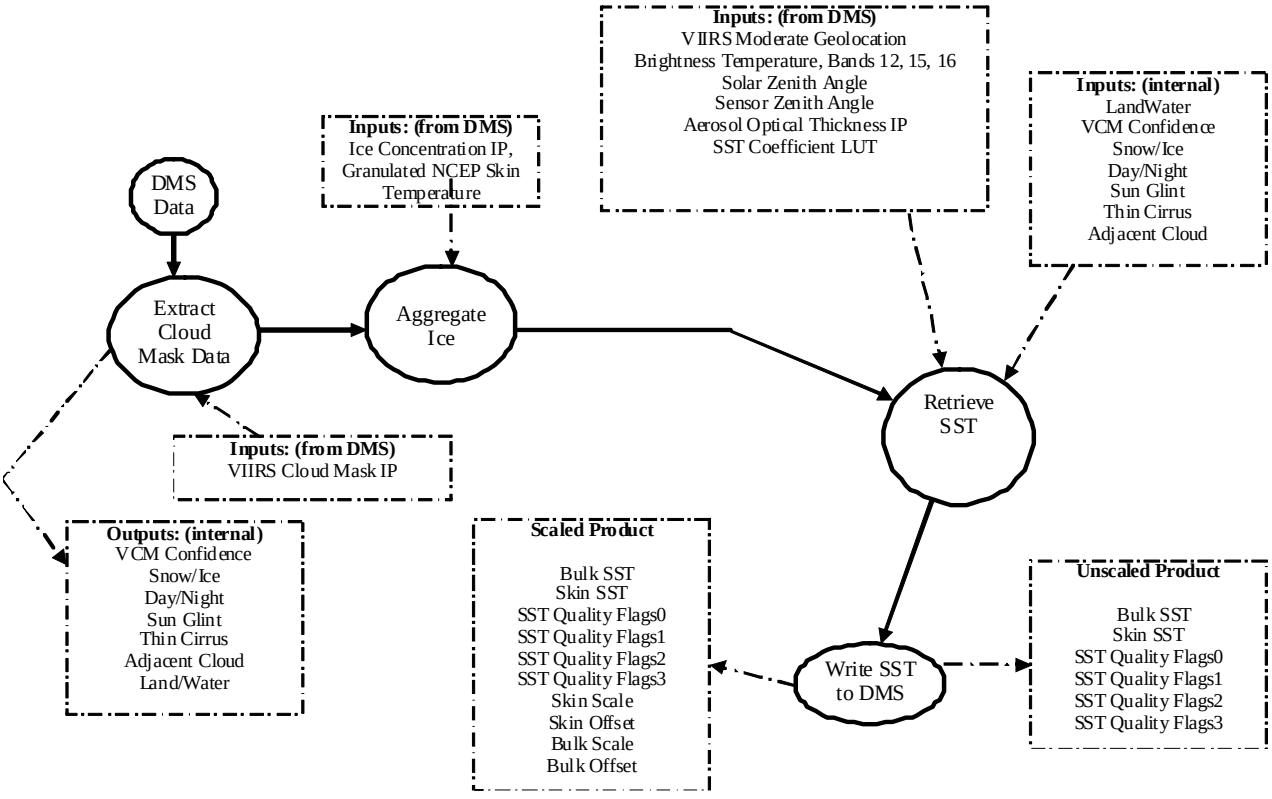

Figure 2. Level 1 Data Flow Diagram of Overall SST Methodology

The VIIRS SST algorithm can run without the following inputs:

- VIIRS-M12-FSDR
- VIIRS-I-Conc-IP
- VIIRS-Aeros-Opt-Thick-IP

The VIIRS SST algorithm has the capability to set the triple-window regression form if sensor data for VIIRS M12 channel is bad. If channels M15 or M16 are missing, the algorithm fills that pixel with a FLOAT32_FILL_VALUE. Snow/ice cover can be determined from the VCM snow/ice surface flag. Additionally at high latitudes, the Ice Concentration IP can be used to identify presence of ice.

2.1.2.1 Main Module - calcSST

All subroutines are called from this procedure—i.e., it controls the flow of the algorithm. The following diagram, Figure 3, shows the calling sequence.

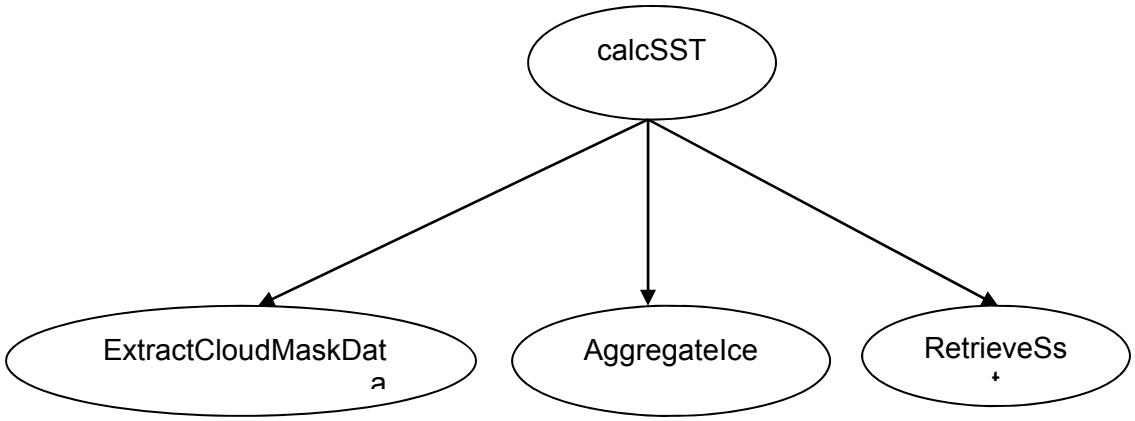

Figure 3. calcSST Calling Sequence Diagram

2.1.2.2 Submodule - ExtractCloudMaskData

This module is used to extract information (quality flags) from the VIIRS Cloud Mask. In addition to cloud cover assessment, the VCM IP provides information on surface type, day/night, and sun glint. The following Cloud Mask flags are extracted from VIIRS Cloud Mask IP:

- LandWater Flag
- Confidence Flag
- Snow/Ice Flag
- Day/Night Flag
- ThinCirrus Flag
- Glint Flag
- Adjacent Cloud Flag

2.1.2.3 Submodule - AggregateIce

This subroutine aggregates imagery resolution ice concentration data to moderate resolution and determines if ice is present based on a configurable threshold.

2.1.2.4 Submodule - RetrieveSST

This process loops through the pixels, performs a series of quality and processing logic tests and computes SST using either the non-linear split window (day) or triple window regression formulas (night). Figure 4 below outlines the processing logic.

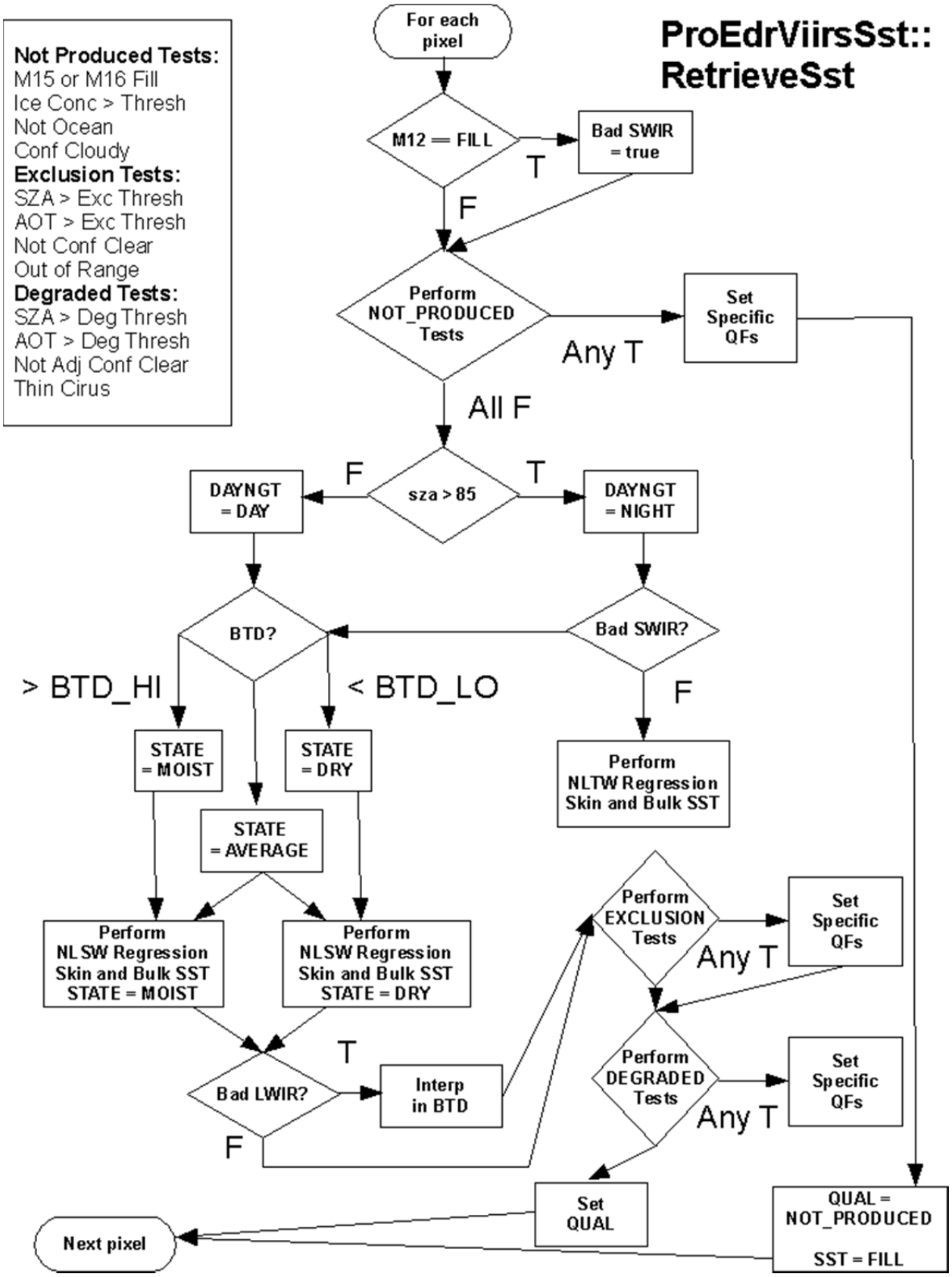

Figure 4. Data Flow Diagram for Retrieve SST

The non-linear split window algorithm is as follows:

$$SST = a_0 + a_1 T_{11} + a_2 (T_{11} - T_{12}) RSST + a_3 (T_{11} - T_{12})(\sec(z) - 1)$$

Where: SST is sea surface temperature in Kelvin

a_0, a_1, $a_{2,\text{ and}}$ a_3 are regression coefficients
T_{11} is the M15 brightness temperature in Kelvin
T_{12} is the M16 brightness temperature in Kelvin
RSST is the NCEP skin temperature in Kelvin (spatially and temporally interpolated)
z is the view zenith angle in radians

The triple window algorithm equation is as follows:

$$SST = a_0 + a_1 T_{11} + a_2 (T_{3.7} - T_{12}) RSST + a_3 (\sec(z) - 1)$$

Where: SST is sea surface temperature in Kelvin

a_0, a_1, $a_{2,\text{ and}}$ a_3 are regression coefficients
$T_{3.7}$ is the M12 brightness temperature in Kelvin
T_{11} is the M15 brightness temperature in Kelvin
T_{12} is the M16 brightness temperature in Kelvin
RSST is the NCEP skin temperature in Kelvin (spatially and temporally interpolated)
z is the view zenith angle in radians

If band M12 is not available, the non-linear split window algorithm is used as a fallback for nighttime processing. Coefficients are retrieved from VIIRS SST Regression Coefficients LUT based on the processing logic stratification. Separate processing coefficients exist for skin and bulk SST, night and day stratifications (NLSW only), and dry and moist stratifications (NLSW only). The dry and moist stratifications are determined by two configurable parameters, btDThresh and dBtDThresh, which are used to determine the dry, average and moist SST State stratifications based on a set of BT15 minus BT16 (BTD) threshold tests. The retrieval of the average stratification is a linear interpolation in BTD between the dry and moist retrievals when the BTD falls about the dry threshold but below the moist threshold.

2.1.2.5 SST QF Logic

SST Flags consist of four 8-bit words as shown in Table 9.

The overall quality of the SST pixel is represented by the Skin and Bulk quality bit fields.

The settings of pixel-level Bulk SST Quality (QF1 offset 2) and Skin SST Quality (QF1 offset 0) are determined by:

The quality flag setting of Not Retrieved is triggered by any of the following:

- Cloud confidence = confidently cloudy

- Not ocean
- SDR M15 or M16 missing
- Ice

The quality flag setting of Excluded is triggered by any of the following:

- Cloud confidence = probably cloudy
- Cloud confidence = probably clear
- AOT > 1.0
- 271 degrees K>Bulk/Skin SST>313 degrees K

The quality flag setting of Degraded is triggered by any of the following:

- Bulk/Skin SST > 305 degrees K
- AOT >= .6
- Satellite Zenith Angle > 40
- HCS flag
- Thin Cirrus present
- Adjacent Cloud present

The quality flag setting of High Quality occurs when all of the above criteria are not triggered:

Confidently Clear, and none of the other degradation, exclusion, or not-retrieved conditions.

2.1.3 Graceful Degradation

2.1.3.1 Graceful Degradation Inputs

There are two cases where input graceful degradation is indicated in the SST:

1. A primary input denoted in the algorithm configuration guide cannot be successfully retrieved but an alternate input can be retrieved.
2. An input that is retrieved for an algorithm has the N_Graceful_Degradation metadata field set (propagation).

Table 10 details the instances of these cases. Note that the shaded cells indicate that the graceful degradation was done upstream at product production.

Table 10. Graceful Degradation

Input Data Descripion	Satellite	Baseline Data Source	Primary Backup Data Source	Secondary Backup Data Source	Tertiary Backup Data Source	Graceful Degradation Done Upstream
Aerosol Optical Thickness	NPP, PM1, TR1	VIIRS_GD_15.4.1 VIIRS AOT IP	VIIRS_GD_25.4.1 NAAPS	VIIRS_GD_15.4.1 Climatology	N/A	Yes, backup only.

2.1.3.2 Graceful Degradation Processing

None.

2.1.3.3 Graceful Degradation Outputs

None.

2.1.4 Exception Handling

To prevent unneeded calculations from occurring, a check was added to verify that the granule contains ocean pixels. In the event that the entire granule is made up of land pixels, the algorithm fills the output buffer with a fill value and returns PRO_SUCCESS. For granules that contain ocean pixels, pixels identified by VCM as confident cloudy are not processed and are also filled with a fill value. Sea ice pixels are also identified and not processed if present.

Each brightness temperature band, specifically bands M15, and M16, are checked for a fill value. If a fill value is present, this value is copied into the same pixel location in the output product.

2.1.5 Data Quality Monitoring

Each algorithm uses specific criteria contained in a Data Quality Threshold Table (DQTT) to determine when a Data Quality Notification (DQN) is produced. The DQTT contains the threshold used to trigger the DQN as well as the text contained in the DQN. If a threshold is met, the algorithm stores a DQN in DMS indicating the test(s) that failed and the value of the DQN attribute. For more algorithm specific detail refer to the CDFCB-X, 474-00001, Volume VI, Appendix C.

2.1.6 Computational Precision Requirements

The NPP VIIRS SST EDR requires accuracy and precision on the order of tenths of Kelvins. Input data used meets this degree of precision requirement. Regression equations are executed using a combination of 32-bit floating-point precision values.

2.1.6.1 Numerical Computation Considerations

In order to retrieve SST within an operational timeframe, statistical algorithms meeting quality requirements have been developed that are much quicker than physical modeling methods. Pre-generated LUTs are used to speed processing yet retain flexibility. Therefore, SST runtime considerations should not pose any serious problems meeting timeliness requirements.

2.1.7 Algorithm Support Considerations

Adjustable parameters for retrieval of SST products allow selection of atmospheric classifications, plus separate selection of retrieval algorithms for skin SST and bulk SST. Flexibility built into the architecture also allows easy implementation of future P^3I developments.

Any thresholds, also referred to as “settable parameters” used in the SST algorithm that can be changed on a frequent basis, are contained within an algorithm specific configuration file.

INF and DMS must be running before the SST algorithm is executed.

2.1.7.1 Program Parameters for Continuous Monitoring

Table 11 shows a list of configurable parameters.

Table 11. VIIRS SST EDR Tunable Parameters

Algorithm Parameter Name	Description	Assigned Value
btDThresh	Moisture stratification threshold	0.8
dBtDThresh	Moisture stratification threshold overlap	0.2
aotDegThresh	AOT degraded threshold	0.6
aotExclThresh	AOT exclusion threshold	1.0
szaUnfThresh	Sensor zenith angle unfavorable threshold	0.6981 Radians
szaExclThresh	Sensor zenith angle exclusion threshold	0.9250 Radians
sstLowThresh	SST low threshold	271.0
sstHighThresh	SST high threshold	313.0
sstDegThresh	SST degraded threshold	305.0
iceConcThresh	Ice Concentration threshold	0.1

2.1.8 Assumptions and Limitations

2.1.8.1 Assumptions

No assumptions are identified at this time.

2.1.8.2 Limitations

The architecture is implemented to retrieve bulk SST radiometrically. Full implementation of a skin to bulk model would require further development of a skin to bulk algorithm.

3.0 GLOSSARY/ACRONYM LIST

3.1 Glossary

Table 12 contains terms most applicable for this OAD.

Table 12. Glossary

Term	Description
Algorithm	A formula or set of steps for solving a particular problem. Algorithms can be expressed in any language, from natural languages like English to mathematical expressions to programming languages like FORTRAN. On NPOESS, an algorithm consists of: 1. A theoretical description (i.e., science/mathematical basis) 2. A computer implementation description (i.e., method of solution) 3. A computer implementation (i.e., code)
Algorithm Configuration Control Board (ACCB)	Interdisciplinary team of scientific and engineering personnel responsible for the approval and disposition of algorithm acceptance, verification, development and testing transitions. Chaired by the Algorithm Implementation Process Lead, members include representatives from IWPTB, Systems Engineering & Integration IPT, System Test IPT, and IDPS IPT.
Algorithm Verification	Science-grade software delivered by an algorithm provider is verified for compliance with data quality and timeliness requirements by Algorithm Team science personnel. This activity is nominally performed at the IWPTB facility. Delivered code is executed on compatible IWPTB computing platforms. Minor hosting modifications may be made to allow code execution. Optionally, verification may be performed at the Algorithm Provider's facility if warranted due to technical, schedule or cost considerations.
cm	Centimeter - unit of measurement for length.
EDR Algorithm	Scientific description and corresponding software and test data necessary to produce one or more environmental data records. The scientific computational basis for the production of each data record is described in an ATBD. At a minimum, implemented software is science-grade and includes test data demonstrating data quality compliance.
Environmental Data Record (EDR)	*[IORD Definition]* Data record produced when an algorithm is used to convert Raw Data Records (RDRs) to geophysical parameters (including ancillary parameters, e.g., cloud clear radiation, etc.). *[Supplementary Definition]* An Environmental Data Record (EDR) represents the state of the environment, and the related information needed to access and understand the record. Specifically, it is a set of related data items that describe one or more related estimated environmental parameters over a limited time-space range. The parameters are located by time and Earth coordinates. EDRs may have been resampled if they are created from multiple data sources with different sampling patterns. An EDR is created from one or more NPOESS SDRs or EDRs, plus ancillary environmental data provided by others. EDR metadata contains references to its processing history, spatial and temporal coverage, and quality.
K	Kelvin - unit of measurement for temperature.
M/s	Meters per second - unit of measurement for velocity.
Model Validation	The process of determining the degree to which a model is an accurate representation of the real-world from the perspective of the intended uses of the model. [Ref.: DoDD 5000.59-DoD Modeling and Simulation Management]
Model Verification	The process of determining that a model implementation accurately represents the developer's conceptual description and specifications. [Ref.: DoDD 5000.59-DoD Modeling and Simulation Management]
Operational Code	Verified science-grade software, delivered by an algorithm provider and verified by IWPTB, is developed into operational-grade code by the IDPS IPT.
Operational-Grade Software	Code that produces data records compliant with the System Specification requirements for data quality and IDPS timeliness and operational infrastructure. The software is modular relative to the IDPS infrastructure and compliant with IDPS application programming interfaces (APIs) as specified for TDR/SDR or EDR code.

Term	Description
Raw Data Record (RDR)	*[IORD Definition]* Full resolution digital sensor data, time referenced, with absolute radiometric and geometric calibration coefficients appended, but not applied, to the data. Aggregates (sums or weighted averages) of detector samples are considered to be full resolution data if the aggregation is normally performed to meet resolution and other requirements. Sensor data shall be unprocessed with the following exceptions: time delay and integration (TDI), detector array non-uniformity correction (i.e., offset and responsivity equalization), and data compression are allowed. Lossy data compression is allowed only if the total measurement error is dominated by error sources other than the data compression algorithm. All calibration data will be retained and communicated to the ground without lossy compression. *[Supplementary Definition]* A Raw Data Record (RDR) is a logical grouping of raw data output by a sensor, and related information needed to process the record into an SDR or TDR. Specifically, it is a set of unmodified raw data (mission and housekeeping) produced by a sensor suite, one sensor, or a reasonable subset of a sensor (e.g., channel or channel group), over a specified, limited time range. Along with the sensor data, the RDR includes auxiliary data from other portions of NPOESS (space or ground) needed to recreate the sensor measurement, to correct the measurement for known distortions, and to locate the measurement in time and space, through subsequent processing. Metadata is associated with the sensor and auxiliary data to permit its effective use.
Retrieval Algorithm	A science-based algorithm used to 'retrieve' a set of environmental/geophysical parameters (EDR) from calibrated and geolocated sensor data (SDR). Synonym for EDR processing.
Science Algorithm	The theoretical description and a corresponding software implementation needed to produce an NPP/NPOESS data product (TDR, SDR or EDR). The former is described in an ATBD. The latter is typically developed for a research setting and characterized as "science-grade".
Science Algorithm Provider	Organization responsible for development and/or delivery of TDR/SDR or EDR algorithms associated with a given sensor.
Science-Grade Software	Code that produces data records in accordance with the science algorithm data quality requirements. This code, typically, has no software requirements for implementation language, targeted operating system, modularity, input and output data format or any other design discipline or assumed infrastructure.
SDR/TDR Algorithm	Scientific description and corresponding software and test data necessary to produce a Temperature Data Record and/or Sensor Data Record given a sensor's Raw Data Record. The scientific computational basis for the production of each data record is described in an Algorithm Theoretical Basis Document (ATBD). At a minimum, implemented software is science-grade and includes test data demonstrating data quality compliance.
Sensor Data Record (SDR)	*[IORD Definition]* Data record produced when an algorithm is used to convert Raw Data Records (RDRs) to calibrated brightness temperatures with associated ephemeris data. Temperature Data Records (TDRs) are geolocated, antenna temperatures with all relevant calibration data counts and ephemeris data to revert from T-sub-a into counts. The existence of the SDRs provides reversible data tracking back from the EDRs to the Raw data. *[Supplementary Definition]* A Sensor Data Record (SDR) is the recreated input to a sensor, and the related information needed to access and understand the record. Specifically, it is a set of incident flux estimates made by a sensor, over a limited time interval, with annotations that permit its effective use. The environmental flux estimates at the sensor aperture are corrected for sensor effects. The estimates are reported in physically meaningful units, usually in terms of an angular or spatial and temporal distribution at the sensor location, as a function of spectrum, polarization, or delay, and always at full resolution. When meaningful, the flux is also associated with the point on the Earth geoid from which it apparently originated. Also, when meaningful, the sensor flux is converted to an equivalent top-of-atmosphere (TOA) brightness. The associated metadata includes a record of the processing and sources from which the SDR was created, and other information needed to understand the data.
Tau	Unit of measurement for Optical Thickness.

Term	Description
Temperature Data Record (TDR)	*[IORD Definition]* Temperature Data Records (TDRs) are geolocated, antenna temperatures with all relevant calibration data counts and ephemeris data to revert from T-sub-a into counts. *[Supplementary Definition]* A Temperature Data Record (TDR) is the brightness temperature value measured by a microwave sensor, and the related information needed to access and understand the record. Specifically, it is a set of the corrected radiometric measurements made by an imaging microwave sensor, over a limited time range, with annotation that permits its effective use. A TDR is a partially-processed variant of an SDR. Instead of reporting the estimated microwave flux from a specified direction, it reports the observed antenna brightness temperature in that direction.
ViirsAncSkinTemp Type	Granulated NCEP Skin Temperature. Data is store in an array of 32 bit floating point numbers. Data is spatially interpolated by the granulation process and is temporally interpolated by a process earlier in the chain.
ViirsAotIPType	VIIRS Aerosol Optical Thickness Intermediate Product. Data is stored in an array of 32 bit floating point numbers.
ViirsCloudMask IPType	A 48-bit word (6 bytes) for each moderate resolution pixel that includes information about whether the view of the surface is obstructed by clouds and specifies the processing path the algorithm took. Cloud phase data is also included as well as spatial uniformity, aerosol, shadow, and fire detection data.
ViirsIceConcIP Type	VIIRS Ice Concentration Intermediate Product. Data is stored in an array of 32 bit floating point numbers.
ViirsModBtType	VIIRS Moderate Resolution Channel Brightness Temperature. Data is stored in an array of 32 bit floating point numbers.
ViirsSnowIce CoverIPType	VIIRS Snow Ice Cover Intermediate Product. Data is stored in an array of 32 bit floating point numbers.
ViirsSstCoeffsLut Type	VIIRS SST Coefficient Look Up Table.

3.2 Acronyms

Table 13 contains terms most applicable for this OAD.

Table 13. Acronyms

Term	Expansion
AM&S	Algorithms, Models & Simulations
API	Application Programming Interfaces
ARP	Application Related Product
CDFCB-X	Common Data Format Control Book - External
DMS	Data Management Subsystem
DPIS ICD	Data Processor Inter-subsystem Interface Control Document
DQTT	Data Quality Test Table
FEDR	Full EDR
INF	Infrastructure
ING	Ingest
IP	Intermediate Product
LUT	Look-Up Table
MDFCB	Mission Data Format Control Book
NAAPS	Navy Aerosol Analysis and Prediction System
NLSW	Non-linear Split Window
QF	Quality Flag
SDR	Sensor Data Record
SI	International System of Units
SST	Sea Surface Temperature
TBD	To Be Determined
TBR	To Be Resolved
TBS	To Be Supplied
TOA	Top of the Atmosphere
VCM	VIIRS Cloud Mask

4.0 OPEN ISSUES

Table 14. TBXs

TBX ID	Title/Description	Resolution date
None		